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OERSTED, HANS CHRISTIAN (*b.* Rudkøbing, Langeland, Denmark, 14 August 1777; *d.* Copenhagen, Denmark, 9 March 1851), *physics.*

Oersted was the elder son of an apothecary, Søren Christian Oersted, and his wife, the former Karen Hermansen. The demands of his father's business and his mother's superintendence of a large family forced his parents to place Hans Christian and his younger brother, Anders Sandøe, with a German wigmaker and his wife while they were still young boys. It was there that Oersted learned German by translating a German Bible and speaking with the couple. The brothers' intellectual abilities were soon apparent, and neighbors did what they could to stimulate and educate them. In this way they picked up the rudiments of Latin, French, and mathematics. When Oersted was eleven, he began to serve as his father's assistant in the pharmacy, thereby gaining a practical knowledge of the fundamentals of chemistry.

This was not much formal education; but when the two brothers arrived in Copenhagen in 1794, they were able to pass the entrance examination for the university with honors. At this point they parted intellectual company; Anders went on to become a jurist and Hans Christian pursued a career in natural philosophy. The most important of Oersted's courses for his intellectual development was that offered on Kant and the critical philosophy. Oersted became a passionate Kantian and defender of Kant's philosophical views, which were to be of fundamental importance to his scientific development. They were even to be the agent that led him to his most important discovery, electromagnetism.

At the University of Copenhagen, Oersted studied astronomy, physics, mathematics, chemistry, and pharmacy. In 1797 he received his pharmaceutical degree with high honors. The following year he became a member of the editorial staff of a new periodical, *Philosophisk repertorium for faedrelandets nyeste litteratur*, which was devoted to the propagation and defense of Kantian philosophy. Although short-lived, the journal provided Oersted with an opportunity to mature his philosophical thinking. An unpublished article that he wrote for it served as the starting point for his doctoral dissertation. In 1799 he received his doctorate with a thesis entitled "Dissertatio de forma metaphysices elementaris naturae externae," which states Oersted's appreciation of the importance of Kantian philosophy for natural philosophy and, in addition, provides a clue to the two areas in which he was to apply his scientific training: electromagnetism and research on the compressibility of gases and liquids.

After a brief stint as the manager of a pharmacy, Oersted set out in the summer of 1801 on a journey that was to complete his scientific education. The scientific world was in ferment over the recently announced discovery of the voltaic pile (1800), and Oersted eagerly pursued information relating to galvanism and its relation to chemistry. A small voltaic battery of his own invention gained him entry to others' laboratories, and he gathered knowledge and ideas as he visited Berlin, Göttingen, and Weimar. Again the influences at work on him were twofold. At Göttingen he was given an introduction to Johann Ritter, who was then publishing on the chemical effects of current electricity. Ritter focused Oersted's attention on the forces of chemical affinity and their relationship to electricity. Ritter's highly unorthodox ideas on matter and force also stimulated Oersted to develop his own concepts. At Berlin he attended lectures on *Naturphilosophie* and met such *Naturphilosophen* as Henrik Steffens and Franz von Baader. He read Schelling and heard Friedrich Schlegel. As a result he developed his philosophical insights by comparing his own metaphysics with those of the *Naturphilosophen*. Since both Oersted and the *Naturphilosophen* drew their inspiration and basic ideas

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from Kant, it is no coincidence that Oersted's later philosophy closely resembled *Naturphilosophie*.

Oersted was saved from the extravagances of a Schelling by his basic respect for empirical fact. Nevertheless, during this trip it was his philosophical penchant that dominated, for although he was suspicious of Schelling's system-building, he swallowed as fact what were only wild guesses by Ritter and the Hungarian chemist J. J. Winterl. Indeed, it was as a defender of Winterl and Ritter that Oersted made his scientific debut in Paris.

The result was disastrous. Winterl's "system" rested on two archetypal substances—Andronia and Thelycke—the essences of acidity and basicity. From these Winterl developed a chemistry of conflicting opposites which, because of its philosophical beauty, completely seduced Oersted. The French chemists, however, were scornful; and Oersted was blasted in the *Annales de chimie et de physique*. It was a valuable lesson. Henceforth, Oersted tended increasingly to hold his philosophical enthusiasms in check at least until he had some evidence for their plausibility. The lesson was driven home by his championing of Ritter's work. To his dismay, he discovered that many of the experimental results his friend reported in the journals were, like Winterl's Andronia, mere figments of his imagination. The pain of having made a scientific fool of himself taught Oersted the critical attitude necessary for the successful pursuit of scientific knowledge.

Oersted returned to Denmark in 1804, preceded by his reputation as an uncritical enthusiast. He had hoped for a professorship in physics but was disappointed by the failure of the warden of the University of Copenhagen to nominate him. He turned, instead, to public lectures, which became so popular that he finally gained an extraordinary professorship in 1806. He then began his own scientific work in earnest. A series of sober publications, among which was an excellent paper on acoustical figures (1810), gradually erased his earlier reputation. He began a steady advance in the academic hierarchy and in reputation. In 1824 he founded the Society for the Promotion of Natural Science and in 1829 became the director of the Polytechnic Institute in Copenhagen, a position that he held until his death. Oersted was a superb teacher and, almost single-handed, raised the level of Danish science to that of the major countries of Europe. He was also an ardent popularizer of science, writing articles and reviews for popular journals. Some of these writings, collected and published as *The Soul in Nature*, reveal his deepest philosophical and scientific beliefs.

There is a unity in Oersted's scientific work that is rarely found in the results of someone whose researches ranged from the forces of chemical affinity, electromagnetism, and the compressibility of fluids and gases to the new phenomenon of diamagnetism. This unity was drawn from Oersted's philosophy, inspired by his reading of Kant. Most Kantian scholars today would insist that Oersted totally misread Kant and came to conclusions to which Kant would have objected. That charge is probably correct; but what is important is that Oersted, and a number of other philosophers and scientists of the time, misread Kant in the same way. Basically, what Oersted thought Kant was saying was that science was not merely the *dis*-covery of Nature; that is, the scientist did not just record empirical facts and sum them up in mathematical formulas. Rather, the human mind imposed patterns upon perceptions; and the patterns were scientific laws. That those patterns were not arbitrary was guaranteed by the existence of Reason. Human reason corresponded to the Divine Reason, for man was made in the image of God. And, inasmuch as God had created Nature, it too shared in the Divine Reason. Thus human reason, unaided, could construct the laws of nature by virtue of its congruence with the Divine Reason. "Was der Geist versprecht, leistet die Natur" is a misquotation from Schiller's *Columbus*—"Mit dem Genius steht die Natur in ewigem Bunde, Was der Eine Verspricht, leistet die andre gewiss"—that Oersted used more than once in *The Soul in Nature*. It represents the basic position of *Naturphilosophie*.

Oersted's reading of Kant led him to more than an attitude toward nature. It also gave him what he felt was a firm metaphysical foundation for his beliefs. In a now neglected treatise, *Metaphysische Anfangsgründe der Naturwissenschaft* (1786), Kant had abandoned some of his agnosticism expressed in the antinomies in the *Critique of Pure Reason*. More particularly, whereas in the *Critique* he had argued that it was impossible for reason to decide between an atomistic or a plenist concept of matter, in the *Metaphysische Anfangsgründe* he came down on the side of the antiatomists. He argued that we experience only force; that force manifests itself in matter as the force of attraction that defines the limits of a body and the force of repulsion that gives a body the property of impenetrability. These two forces Kant called *Grundkräfte* (basic forces). Other forces, such as electricity, magnetism, heat, and light, he hinted, were merely modifications of the *Grundkräfte* under different conditions.

Oersted read both the *Critique of Pure Reason* and the *Metaphysische Anfangsgründe* while still at the university. His doctoral dissertation is a defense of

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the *Metaphysische Anfangsgründe* and an attempt to have it accepted in Denmark as a basic philosophical treatise. As early as 1800 it is possible to discern the two elements that were fundamental in Oersted's later scientific work: the clear enunciation of the doctrine of forces and the disbelief in atoms. The first was to lead him, through the convertibility of forces, to the discovery of electromagnetism; the second seems to have been the stimulus behind his work on compressibility, for if solid, incompressible atoms existed, there ought to come a point when further compression of a gas or fluid was impossible.

In 1800, however, Oersted's ideas were only half-formed. He was far more *au courant* in philosophy than he was in science. This is why his journey to Germany and France was so crucial. It acquainted him with men who were at the frontiers of science and forced him to bring his philosophical speculations down to earth.

The reentry was a difficult one. The "new" chemistry of Lavoisier and the other French chemists left him unmoved because it turned its back on the very questions, such as elective affinity and the true nature of acids and bases, that fascinated Oersted. Winterl's system, on the other hand, was just what he was looking for. Instead of some thirty-odd elements, defined only empirically as the last products of a laboratory analysis, Winterl offered two fundamental and opposed substances. Andronia and Thelycke could be viewed as materializations of the *Grundkräfte* and chemistry could then, it was hoped, be seen as a Kantian science. Similarly, Ritter's work in electrochemistry appeared to Oersted as a development of Kantian thought and all of a piece with his own philosophy of forces. It was only when his philosophical theories and the empirical facts refused to fit together in repeatable experiments that Oersted's critical faculties were awakened. It is significant that, at this point, he did not reject his philosophical faith. Instead, he rejected the physical systems of Winterl and Ritter. His first real scientific achievement was to create his own system, based upon his own experiments. The results appeared in German in 1812 and in a French translation in 1813. The title of the latter, *Recherches sur l'identité des forces chimiques et électriques*, indicates its purpose. From the *Grundkräfte*, Oersted hoped to deduce a system of chemistry that would be in accordance with the results of experiment.

The *Recherches* is an undeservedly neglected work of theoretical chemistry. The standard histories of chemistry barely mention it, yet it tried to come to grips with some of the major problems of the day. Specifically, it sought to make some sense of the various chemical reactions involved in combustion and the neutralization of acids and bases. By 1813 Lavoisier's theory of acids and of combustion could be severely criticized. Humphry Davy's work on chlorine showed that oxygen was not the only supporter of combustion. The fact that hydrochloric acid contained no oxygen also proved that oxygen was not, as Lavoisier had claimed, the principle of acidity. Oersted now tried to show how one could create a new chemistry based on forces, not elements.

According to Oersted, the Kantian *Grundkräfte* of attraction and repulsion manifest themselves in chemistry as combustibles and combusters. These forces are in conflict and when allowed, in combustion, to come to grips with one another, so to speak, produce the light and heat that are so preeminently the effects of combustion. But these two forces do not annihilate one another chemically; instead, they produce a higher synthesis—the acids and bases. Acidity and basicity, in turn, are opposites which unite to form the neutral salts. The supposedly Hegelian triad of thesis-antithesis-synthesis is here clear and is a standard aspect of *Naturphilosophie*. Although this analysis of fundamental chemical processes did provide a conceptual unity where before there was chaos, it left little impression upon Oersted's colleagues. Nor did his final chapters, in which he examined the convertibility of other forces. By 1813 everyone admitted the chemical role of electricity, but Oersted's treatment of it seemed to be of little help. What is of interest, at least to historians of science, is his discussion of the possibility of the conversion of electricity into magnetism.

It is important to stress that electromagnetism was not an effect to be expected according to the orthodox, corpuscular theories of the day. Coulomb seemingly had proved in the 1780's that electricity and magnetism were two entirely different species of matter whose laws of action were mathematically similar but whose natures were fundamentally different. The conversion of one into the other was, literally, unthinkable. Hence, those who accepted Coulomb's findings simply did not look for a magnetic effect.

For Oersted the situation was quite different. The Kantian doctrine of *Grundkräfte* led directly to the idea of conversion of forces. All that was necessary was to discover the conditions under which such conversions took place. The particular conditions for the conversion of electricity into magnetism were deduced by Oersted from the nature of electricity. Electricity to him was a conflict of the positive and negative aspects of magnetism, which conflict spread out in wave fashion in space. When the electric conflict was confined in a rather narrow-gauge wire, the result

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was heat. When the conflict was restricted still further by decreasing the diameter of the wire, light was produced. So, Oersted suggested in his treatise on the identity of chemical and electrical forces, the magnetic force should be produced when the electrical conflict is still further confined in a very narrow-gauge wire. In 1813, therefore, he had already predicted the existence of the electromagnetic effect. He was wrong, of course, on the conditions; and this error, together with his increasing teaching duties in the years that followed, prevented him from bringing his prediction to reality. The actual discovery was made in the early spring of 1820 and may best be given in Oersted's own words.

> Electromagnetism itself was discovered in the year 1820, by Professor Hans Christian Oersted, of the University of Copenhagen. Throughout his literary career, he adhered to the opinion, that the magnetical effects are produced by the same powers as the electrical. He was not so much led to this, by the reasons commonly alleged for this opinion, as by the philosophical principle, that all phenomena are produced by the same original power. . . . His researches upon this subject, were still fruitless, until the year 1820. In the winter of 1819-20, he delivered a course of lectures upon electricity, galvanism, and magnetism, before an audience that had been previously acquainted with the principles of natural philosophy. In composing the lecture, in which he was to treat of the analogy between electricity and magnetism, he conjectured, that if it were possible to produce any magnetical effect by electricity, this could not be in the direction of the current, since this had been so often tried in vain, but that it must be produced by a lateral action. This was strictly connected with his other ideas; for he did not consider the transmission of electricity through a conductor as an uniform stream, but as a succession of interruptions and re-establishments of equilibrium, in such a manner that the electrical powers in the current were not in quiet equilibrium, but in a state of continual conflict. . . . The plan of the first experiment was, to make the current of a little galvanic trough apparatus, commonly used in his lectures, pass through a very thin platina wire, which was placed over a compass covered with glass. The preparations for the experiments were made, but some accident having hindered him from trying it before the lecture, he intended to defer it to another opportunity; yet during the lecture, the probability of its success appeared stronger, so that he made the first experiment in the presence of the audience. The magnetical needle, though included in a box, was disturbed; but as the effect was very feeble, and must, before its law was discovered, seem very irregular, the experiment made no strong impression on the audience ["Thermo-electricity," in *Edinburgh Encyclopaedia* (1830), XVIII, 573–589; repr. in Oersted's *Scientific Papers*, II, 356].

Oersted could not be sure that the effect was the one he had anticipated, and therefore he deferred working on it for some three months. In July he resumed his researches and made certain that a current-carrying wire is surrounded by a circular magnetic field. The results appeared in a short paper, written in Latin, sent to the major scientific journals in Europe. The "Experimenta circa effectum conflictus electrici in acum magneticam," dated 21 July 1820, opened a new epoch in the history of physics. From it followed the creation of electrodynamics by Ampère and Faraday's *Experimental Researches in Electricity*.

Oersted's second major area of research involved the compressibility of gases and fluids. It may be, as his biographer Kirstine Meyer implies, that he became interested in this problem by noting inconsistencies in the experiments of previous investigators. There may also, however, be a matter of theoretical importance involved. In all his experiments on compressibility, especially the compressibility of fluids, Oersted was intent upon proving that the reduction in volume was proportional to the pressure. If this were so, then the law of compressibility would provide a smooth pv curve. The existence of incompressible atoms, occupying space, would force a discontinuity in this curve if and when the point could be reached when the atoms were packed tightly together. Oersted's system of forces permitted continual compression, and it seems plausible that his experiments on compressibility were intended to test the atomic hypothesis. The results were inconclusive, but his apparatus and critical acumen in detecting sources of error were of basic importance for later investigations of compressibility.

Oersted's last scientific researches were on the phenomena of diamagnetism. He tried to account for diamagnetic substances by assuming reverse polarity and reverse inductive effects in substances that were repelled from, rather than attracted to, a magnetic pole. This work, in the late 1840's, was made obsolete by Faraday's investigations, which showed that the concept of polarity could not be applied to diamagnetics.

In his last years Oersted returned to his first love, philosophy. In a series of articles, published together in *The Soul in Nature*, he considered the relation between beauty and science. He still saw the hand of God in both. Beauty in art and music was the Divine Reason manifested in the harmonies of sight and sound. "Spirit and nature are one, viewed under two different aspects. Thus we cease to wonder at their harmony." Oersted's last work, *The Soul in Nature*, was left unfinished when he died on 9 March 1851. It was intended to express, in final form, the faith that had guided his entire scientific career.

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II. SECONDARY LITERATURE. The only biography to deal with Oersted's entire scientific life is that by Kirstine Meyer, which introduces the *Scientific Papers*.

There are a number of specialized studies on Oersted. Bern Dibner, *Oersted and the Discovery of Electromagnetism* (Norwalk, Conn., 1961), is a study of Oersted's most important work. Robert C. Stauffer's "Speculation and Experiment in the Background of Oersted's Discovery of Electromagnetism," in *Isis*, **48** (1957), 33 ff.; and "Persistent Errors Regarding Oersted's Discovery of Electromagnetism," *ibid.*, **44** (1953), 307 ff., first drew scholarly attention to the importance of *Naturphilosophie* for an understanding of Oersted's scientific career.

L. PEARCE WILLIAMS